DEEP-SEA BOTTOM HANDLINE FISHING IN PAPUA NEW GUINEA: A PILOT STUDY

Per Sundberg* and Andrew Richards†

ABSTRACT

Bottom handlining was performed in three areas: Port Moresby, Milne Bay and Manus. It was shown that the catch rates are not Poisson distributed, i.e. they are not random, but no differences in catch rates could be found between the three areas, the time of the day or between different depths in the range fished, 70-270 m. It is concluded that the clumped distribution of the catch rates is probably due to different bait or by fishing at different sites, or both.

Differences in mean weight of fish were found for different depths, with a general trend for fish weight to increase with depth. The mean weight at 200-210 m is significantly higher than at depths 140-150 m and mean weight at 220-270 m is significantly higher than at depths 80-110 and 140-190 m.

Depth distributions are given for the 15 most common species encountered: Gnathodentex mossambicus, Lutjanus argentimaculatus, L. malabaricus, Pristipomoides multidens, P. flavipinnis, Etelis carbunculus, E. coruscans, E. radiosus, Tropidinus zonatus, T. argyrogrammicus, Tangia *sp.*, Epinephelus compressus, E. magniscuttis, E. morrhua *and* Epinephelus *sp. The depth associations between these species are described by cluster analysis based on a similarity matrix.*

INTRODUCTION

Interest in the deep water resources of the South Pacific is increasing for three reasons: first, stocks of demersal fish (fish living on, or close to, the seabed) are limited because of the almost complete absence of continental shelf, second, the overfishing of demersal stocks in those areas where they exist, and third, the problem of ciguatera poisoning does not exist with the deep water fish.

The South Pacific Commission (SPC) has been involved in deep water projects since 1974 (Crossland and Grandperrin 1980), and has endeavoured to both teach and encourage handline bottom fishing.

In early 1982, SPC staff visited Papua New Guinea to carry out a training programme in deep water handlining. Information on catch rates and catch composition was collected during this training programme and was analysed to describe the differences in catch rates between the three areas fished (Port Moresby, Milne Bay and Manus), the distribution of catch rates with respect to depth and time of day, and the depth distribution for the most common species. The depth and abundance associations between these species were also analysed.

This paper deals only with teleost (bony) fish. In some areas however, a substantial part of the catch consists of elasmobranchs (sharks).

* Research and Survey Branch, Fisheries Division, Department of Primary Industry, P.O. Box 417 Konedobu, Papua New Guinea. Present Address: University of Gothenburg, Department of Zoology, P.O. Box 250 59, S-400 31 Gothenburg, Sweden.

† Fisheries Research Laboratory, P.O. Box 101, Kavieng, Papua New Guinea.

MATERIALS AND METHODS

Fishing

Three areas were fished: Port Moresby (seven trips, 41 hours fishing), Milne Bay (four trips, 65 hours fishing) and Manus (four trips, 61 hours fishing) (*Figure 1*). Fishing trips lasted from two hours to three days and depths ranged from 70 to 270 m. Small launches (6-8 m) were used on all trips except one where fishing was undertaken from a 10 m research vessel.

Fishing in Milne Bay and Manus was carried out on the slopes of the fringing reefs, i.e. where there is a shelf of coral growth, while in Port Moresby the outer slope of a barrier reef, i.e. a reef parallel to, but at some distance from the shore, was fished. All fishing was done from anchored positions; the anchor was dropped in shallow water and the rope paid out until a suitable depth was reached. Depths were determined with a Japan Marina Co., model 707 A/B, echo-sounder.

Fish were hauled by hand-reels of the Samoan type, equipped with over 300 m of monofilament line (125 kg test) and a wire terminal rig with three Mustad hooks, sizes 5, 6 and 7. A detailed description of the fishing gear is given by Fusimalohi and Crossland (1980).

The bait varied according to availability. The main baits used were skipjack tuna (*Katsuwonus pelamis*), dogtooth tuna (*Gymnosarda nuda*) and different mackerel species. It was either used fresh or toughened with salt.

Analyses

If there is a random temporal and spatial dispersion of catch rates, they will follow a Poisson distribution. A property of this distribution is that the variance is equal to the mean, a property that can be used as a test of randomness. If the catch rates are distributed randomly the ratio variance/mean value should equal one (Sokal and Rohlf 1981) and to test this the ratio A is used (Elliot 1971).

$A = \{ s^2 (n-1) \} \cdot \bar{x}^{-1}$

where:

s^2 = the variance of the catch rates

$\bar{x}$ = the mean value

n = the sample size.

This ratio is approximately χ^2 distributed with $n-1$ degrees of freedom (d.f.).

Catch rates are in kg of ungutted fish caught per line and hour. Differences in the catch rates between areas, time of day and depths, together with differences in average weight of fish for different depths, were analysed by the non-parametric Kruskal-Wallis one-way analysis of variance (ANOVA) (Daniel 1978). When significant differences were found, an *a posteriori* comparison was made by the procedure proposed by Dunn (1964), and described in Daniel (1978). An experimentwise error rate (Daniel 1978; Sokal and Rohlf 1981) of 0.15 was used in this comparison.

Ecological associations with respect to depth distribution and abundance were analysed using the two cluster analysis techniques: unweighted pair-group method using arithmetic averages (UPGMA) (Sokal and Michener 1958; Sneath and Sokal 1973), and single linkage clustering (Sneath 1957; Sneath and Sokal 1973). The cluster analyses were based on the similarity coefficient S.

$S = .5 \{ A \cdot (A + B + C)^{-1} + 2W \cdot T^{-1} \}$

where:

A = the number of depths where species i and j occur together

B = the number of depths where i, but not j, is present

C = the number of depths where j, but not i, is present

W = the sum of the lesser number of specimens for the species common to both depths

T = the total number of specimens for i and j.

This coefficient is a combination of the Jaccard (1908) and Bray-Curtis (in Southwood 1978) coefficients. The reason for

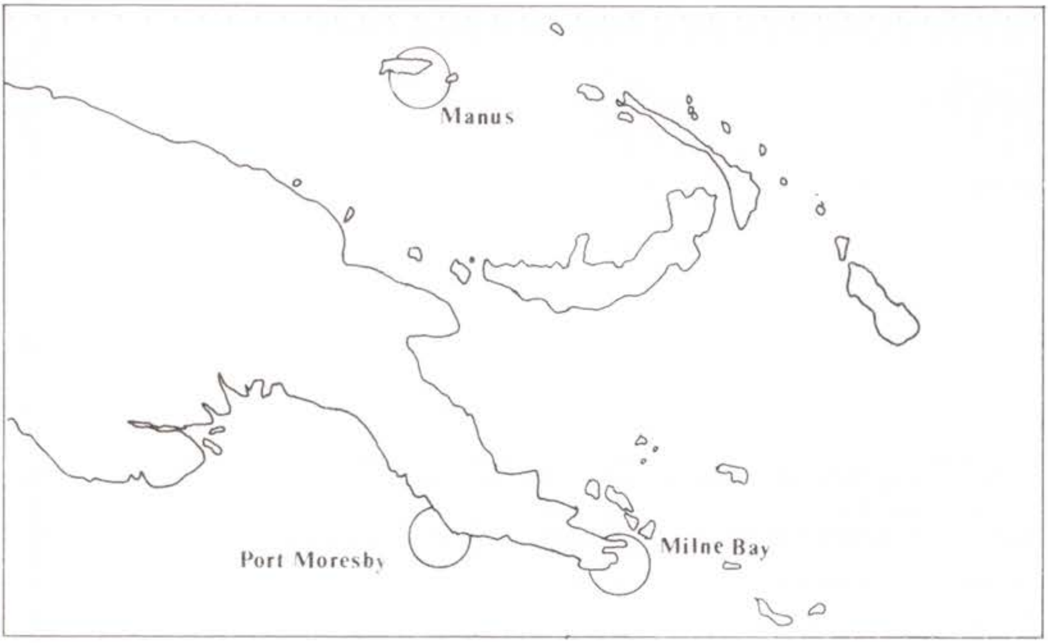

Figure 1. — **A map of Papua New Guinea, showing the three fishing areas used in this study; Port Moresby, Milne Bay and Manus**

combining them is that the former does not take into account abundance and will give high similarity even if some of the species are rare, whilst the Bray-Curtis coefficient underestimates the ecologically important fact that two species do occur together, even though their abundances are low.

RESULTS AND DISCUSSION

Catch rates and species composition

The mean catch rates are given in *Table 1* and the species encountered are listed in *Table 2*, which also lists where the species have been caught elsewhere in the South Pacific. The most common species are *Etelis carbunculus, Epinephelus morrhua, Tropidinus zonatus*, and *Lutjanus bohar*.

The differences between the rates are not statistically significant for the three areas (ANOVA, $P<0.05$). For comparison, some other catch rates obtained by the same method of fishing in the South Pacific region are listed in *Table 3*.

The mean catch rate in this study, is about the average for the region and is at a level which could probably support an artisanal, i.e. small-scale, fishery. Although it was not possible to demonstrate in this study, it is our impression that the bait used has a significant influence on catch rates, a finding supported by Fusimalohi (pers. comm.). It is likely that oily fish with red flesh, such as skipjack tuna, produce higher catch rates. It should be pointed out that most of the fishing was undertaken by inexperienced trainees and catch rates can be expected to increase with experience of the crew.

Catch rates, depth and time of the day

Since this study was carried out in conjunction with a training programme, not all depths and times of the day could be fished in all areas. Hence for the analyses in this section, and the test of differences

Table 1. — **Mean catch rates for the three areas fished**

Area	Mean catch rate (kg/hr x No. of lines)	95% confidence interval	Sample size (hours of fishing)
Port Moresby	3.99	2.07	41
Milne Bay	2.50	0.74	65
Manus Island	4.55	1.74	61
Pooled	3.68	0.85	167

Table 2. — **List of the species encountered in Papua New Guinea and elsewhere in the South Pacific**

Species	No. of fish	% per weight	Mean weight	Source[4]					
				A	B	C	D	E	F
Etelis carbunculus	111	47.2	4.9	X	X	X	X	X	X
Pristipomoides multidens	44	8.22	2.1	X	X				X
Etelis coruscans[1]	15	5.76	4.4	X	X	X			X
Epinephelus magniscuttis	13	5.58	4.9		X			X	X
Lutjanus malabaricus	11	1.30	1.4						X
Gnathodentex mossambicus	10	1.73	2.0						X
Epinephelus morrhua	9	1.61	2.0	X	X[3]	X	X	X[3]	X
Tropidinus zonatus	9	1.01	1.3	X		X	X	X	X
Pristipomoides flavipinnis	8	0.45	0.6	X	X[3]	X		X[3]	X
Epinephelus compressus	5	12.1	27.6	X					
Lutjanus argentimaculatus	5	2.25	5.1			X		X	X
Etelis radiosus[2]	5	2.18	5.0						
Epinephelus sp.	5	0.31	0.7		X[3]			X[3]	
Tangia sp.	4	1.34	3.8						
Pristipomoides filamentosus	4	1.13	3.2	X	X[3]			X[3]	X
Tropidinus argyrogrammicus	4	0.16	0.5	X					X
Epinephelus chlorostigma	3	0.45	1.7		X[3]	X		X[3]	X
Lutjanus bohar	2	1.06	6.1	X		X	X	X	X
Lethrinella miniata	2	0.87	5.0	X		X		X	X
Seriola dumerilii	2	0.48	2.8						
Variola louti	2	0.07	0.4	X		X	X		X
Pristipomoides auricilla	2	0.07	0.4		X[3]	X		X[3]	
Leptocephalidae	1	0.93	10.6						
Epinephelus tauvina	1	0.91	10.4		X[3]	X		X[3]	
Seriola purpurescens	1	0.49	5.6					X	X
Caranx lugubris	1	0.44	5.0				X	X	
Gymnosarda nuda	1	0.40	4.6						
Caranx sp.	1	0.39	4.4			X		X	X
Lutjanus erythropterus	1	0.37	4.2						
Lettrinus kallopterus	1	0.27	3.1						
Paracaesio sp.	1	0.26	3.0						
Branchiostegus wardi	1	0.13	1.5						
Cephalopholis sp.	1	0.02	0.02						

[1] *Etelis coruscans* is identified from Anderson (1981).
[2] *Etelis radiosus* is a recently described species (Anderson 1981).
[3] The source only reports the genus, not the species
[4] A. Fusimalohi and Grandperrin 1979
B. Fusimalohi 1979
C. Taumaia and Crossland 1980
D. Mead 1980a
E. Mead and Crossland 1980
F. Mead 1980b

Table 3. — **Mean catch rates (kg/h x No. of lines) of bony fish, obtained by the South Pacific Comission deep sea fisheries development project in different places around the South Pacific area**

Place	Average Catch	Source
New Caledonia	7.1	Fusimalohi and Grandperrin 1979
Niue (1979)	7.0	Mead 1980a
Palau	3.0	Taumaia and Crossland 1980
Tanna	2.8	Fusimalohi 1979
West New Britain	4.3	Fusimalohi and Crossland 1980
Yap Island	4.6	Mead and Crossland 1980
Fiji	9.2	Mead 1980b

in average weights, data from the three areas have been pooled.

The calculated value of the ratio variance/mean value is significantly higher than one (χ^2-test, $P<0.001$, d.f. $=166$) and hence the catch rates are clumped in their distribution, with one group of low catch rates and a second with high. However, the test for differences in catch rates for different times of the day, and differences in catch rates at different depths shows that no differences could be found (ANOVA, $P<0.005$, d.f. $=22$ and 8 respectively) and hence fishing at different depths or at different times of the day is not the cause of this clumping of catch rates.

Rather we hold the view that the uneven distribution of catch rates was caused by a combination of bait effectiveness and whether or not fishing was undertaken in a good place. By bait effectiveness we then mean, as mentioned above, that certain bait seems to give higher catch rates. From our experience it is also apparent, even if we have not been able to show it statistically due to the sampling programme, that certain places within an area yielded high catch rates, whilst others, irrespective of depths and time of day, did not.

Depth association among the 15 most common species

The results of the two cluster analyses are illustrated in *Figure 2*. Two different independent clustering methods are used to assess the stability of the groupings. Since both methods produce similar results, this suggests that they reflect the true association between the species.

From a practical point of view, a knowledge of species associations is of interest since it gives information on species expected to be caught together. This could in turn be useful in the planning, and the assessment, of a fishery. *Figure 2* indicates for instance that *Etelis coruscans, Epinephelus compressus, E. magniscuttis, E. morrhua* and *Gnathodentex mossambicus* will be caught together. Similarly, other associations can be discerned by examining *Figure 2*, and higher similarity values can be interpreted as higher probabilities of being encountered together.

Species composition, mean weights and depth

The depth distribution for the 15 most commonly encountered species are depicted in *Figure 3*.

The average weight of fish, irrespective of species, (*Table 4*) is significantly higher at certain depths (ANOVA, $P<0.001$, d.f. $=9$) with a general trend for fish weight to increase with depth. The average weight at 200-210 m is significantly higher than at depths 140-150 m and the average weight at 220-270 m is higher than the average weights at 80-110 and

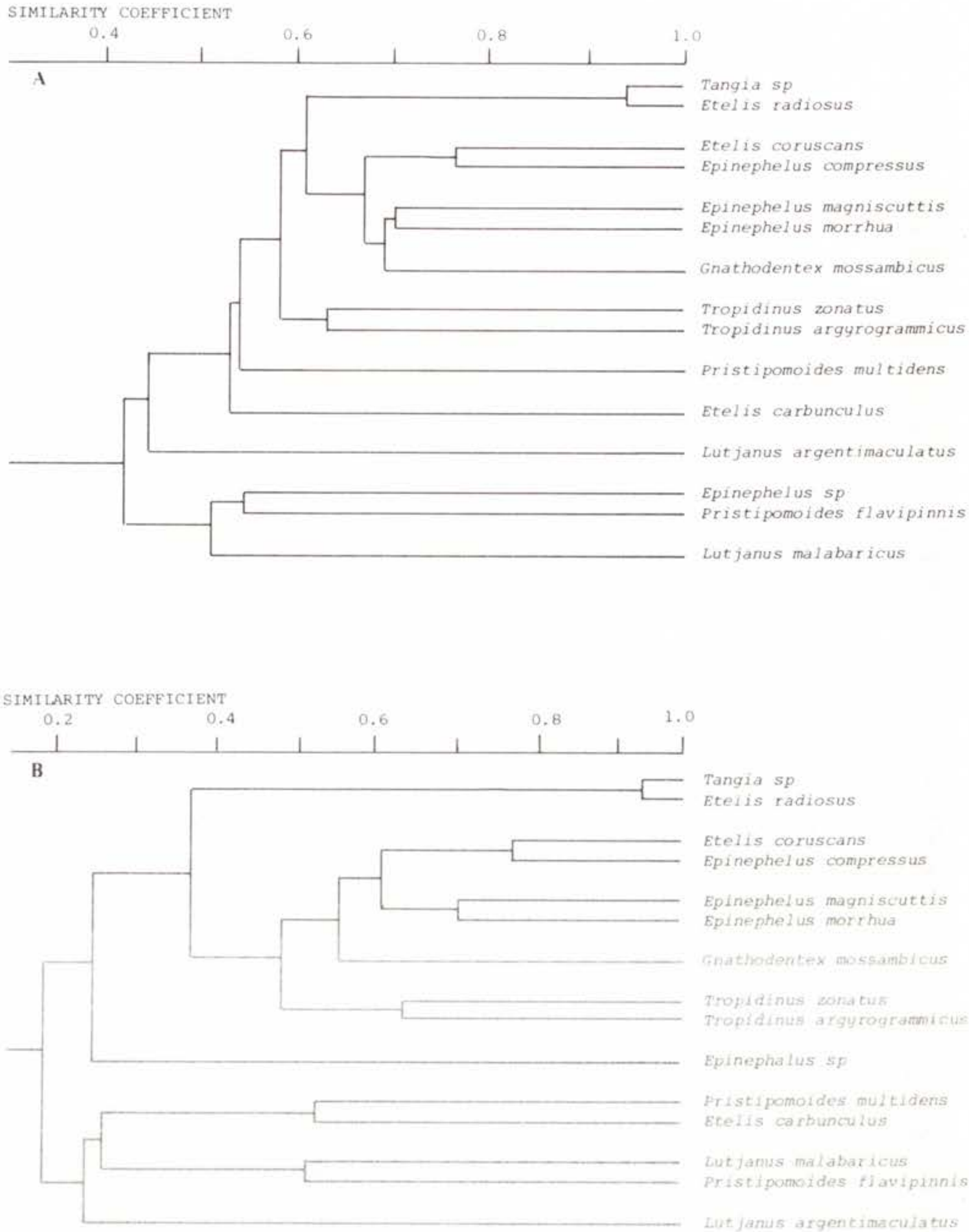

Figure 2.—**Cluster analysis of the depth associations between the 15 most common species. Based on a combination of the similarity coefficients proposed by Jaccard (1908) and Bray-Curtis (in Southwood, 1978). 2A. Single linkage clustering 2B. Unweighted pair-group method using arithmetic averages (UPGMA)**

Table 4. — **Mean weight of fish for different depth intervals**

Depth (m)	Mean weight (kg)	95% confidence interval	Sample size
80 – 90	1.6	1.1	8
100 – 110	2.2	1.0	15
120 – 130	3.3	1.5	15
140 – 150	1.3	0.9	12
160 – 170	2.3	0.5	21
180 – 190	3.1	1.1	40
200 – 210	4.3	1.3	47
220 – 230	4.9	0.7	20
240 – 250	5.8	2.9	51
260 – 270	4.8	1.2	56

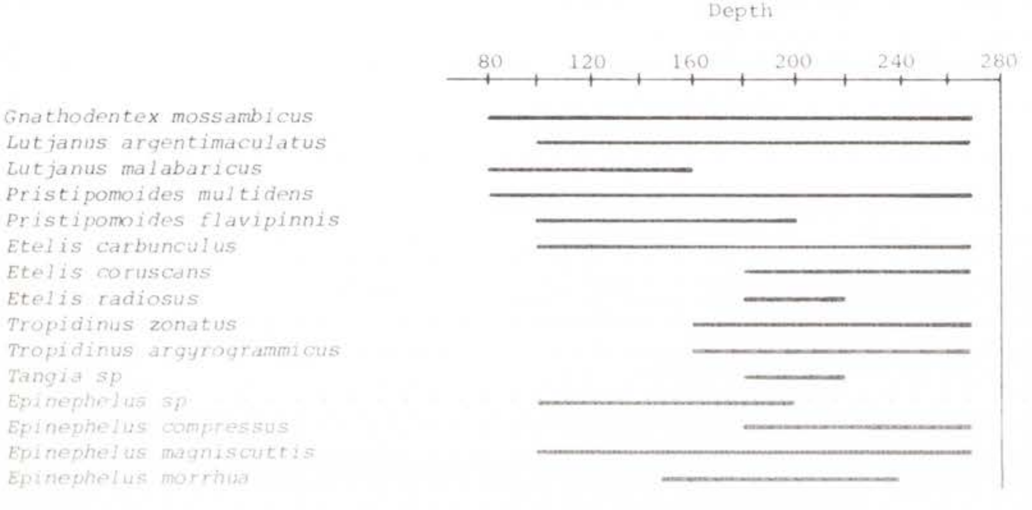

Figure 3. — **Depth distribution of the 15 most common species**

140-190 m. The depth range is divided into 20 m intervals, because even though the echosounder will give a precise reading, it is not possible to know exactly where the hooks are.

Since there is no significant variation in catch rate with depth, fishing at greater depths yields bigger but fewer fish. Unless certain species, or large fish are sought, it could therefore be more beneficial to fish in shallower water.

CONCLUSIONS

Based on the limited data from 41-65 hours of fishing in each locality, no significant difference in average catch rate between the three areas, Port Moresby, Milne Bay and Manus, could be found. The mean catch rate is 3.7 $\pm$0.85 ($\pm$95% confidence interval).

The available data do not indicate any differences in catch rates between different times of the day, or between different depths. The distribution of the catch rates is however contagious which indicates that there are factors influencing the catch rate.

There is a significant difference in average weight at different depths, so that the average weight is higher at 200-210 m than at 140-150 m, and the average weight is higher at 220-270 m than at 80-110 and 140-190 m.

Certain of the 15 most common species are more likely to be encountered together. The most likely combinations are: *Tangia* sp. and *Etelis radiosus; Etelis coruscans* and *Epinephelus compressus; Epinephelus magniscuttis* and *E. morrhua* (similarity of 0.7, using a combination of the Jaccard and Bray-Curtis coefficients, chosen as an arbitrary limit for grouping).

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